EFFECTIVENESS OF AUGMENTED REALITY APPLICATION OF MOLECULAR GEOMETRY MATERIAL WITH AN ETHNOCHEMISTRY APPROACH TO SUPPORT DISTANCE LEARNING

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Abstract

Augmented Reality mobile learning media in learning chemistry can make it easier for learners to understand abstract concepts by visualizing atoms, molecules, bonds, and intermolecular interactions that look like real. In 2023, the design of "BRIMOLANG: Learning Molecular Forms through Palembang Culture" which is a mobile learning augmented reality that uses an ethnochemical approach. After the application was developed, a public test was conducted on distance education students to determine the effectiveness of the application developed. This study had 310 respondents whose application public test was conducted in May-June 2024. Based on the results of the feasibility test, it can be concluded that the resulting application has met the criteria very well and is suitable for use as a learning medium on molecular geometry material. This media can support molecular geometry learning because it uses AR technology so that it can increase knowledge of the material and can also hone the spatial abilities of distance students that can be used anytime and anywhere.

Keywords: learning chemistry, learning media, augmented reality, molecular geometry, application effectiveness.

1 INTRODUCTION

Distance Learning (DLE) has become one of the main solutions in providing broad access to education for students who are hampered by time, geography, and economic factors. With the increasing development of technology, many innovations are applied in DLE to increase the effectiveness and interactivity of learning. In the IT world, Augmented Reality (AR) is currently a hot topic. AR allows the integration of digital objects into the real world, creating a more interactive and immersive learning experience. In the context of chemistry learning, especially molecular geometry material, AR offers a new way to understand the structure and dynamics of molecules more intuitively and visually. In the field of chemistry, augmented reality mobile

learning media can facilitate the understanding of abstract concepts by providing students with realistic representations of atoms, molecules, bonds, and intermolecular interactions. Students can interact and observe the overall shape of molecules by displaying microscopic atoms and molecules in the real world (Damanik & Silaban, 2024).

Three levels of representation can be visualized using modeling. According to Coll and Lajium (in Supriadi et al., 2023), chemistry learning can take place effectively if modeling is used. There are three important goals in chemical modeling, namely to create a simple form of an object or concept; provide stimulation in concept formation during learning so as to support visualization of a phenomenon; and provide an explanation of scientific phenomena (Ünal et al., 2006). The integration of augmented reality (AR) technology into the classroom is one potential approach to chemical modeling. According to Latipah (2021), augmented reality-based learning has the potential to improve students' conceptual frameworks.

Augmented reality technology is very good for modeling the submicroscopic level of a substance so that it can connect the three levels of representation. The method relies on image detection with images functioning as markers (Ginting et al., 2017). Images can be macroscopic levels of a substance, then the detection results will display the chemical formula and molecular shape of the compounds in the substance (Rajmah et al., 2017). AR technology can be used as distance learning if conditions do not allow for face-to-face learning (Pakpahan & Fitriani, 2020).

According to Sirakaya (2018), students like augmented reality technology to teach abstract ideas because it takes into account various stages of cognitive development. Projection of molecular geometric objects is needed for molecular geometry, which is the study of abstract material. Generally, students are still lacking in the concrete operational stage to explain a concept, there needs to be a real object or event that can be accepted logically. Molecular geometry teaching materials can be visualized in real time through the use of AR technology (Sungkur, 2016).

Although various learning technologies have been developed to improve student understanding, such as Augmented Reality (AR), these applications often do not take into account the local cultural context that can increase the relevance and motivation of students to learn. The ethnochemical approach, which integrates local cultural values into the learning process, has not been widely applied in the development of technology-based learning media such as AR. Previous studies have shown that Chemistry Education can improve students' understanding of

complex concepts through the application of AR. For example, research by Supriono dan Rozi (2018) showed that AR applications can help visualize chemical molecular geometry more effectively. However, this study has not combined aspects of learning motivation and local cultural context that are relevant to students.

Ethnochemical approaches, which relate chemical concepts to local culture and traditional knowledge, are also gaining importance. Ethnochemistry helps students understand the relevance of chemistry in their everyday contexts, making the subject matter more meaningful and understandable. The domains of science and education can be stimulated by ethnochemistry (Selasih & Sudarsana, 2018). In addition, chemistry education strategies that include local knowledge can be built on the foundation of ethnochemistry. Teachers and students can gain a deeper understanding of their own culture and the importance of preserving and utilizing the natural environment by bringing this learning closer to the real-life situations they encounter (Suratno, 2010).

The combination of AR and ethnochemistry has great potential to enhance molecular geometry learning, especially for distance learning students who may have limited access to conventional learning resources. In addition to allowing students to visualize molecular structures in three dimensions, AR technology can also offer an interactive and immersive learning experience. Meanwhile, the ethnochemistry approach enriches learning by integrating local wisdom and cultural context in understanding chemical concepts. Thus, the integration of AR and ethnochemistry not only enhances theoretical understanding but also encourages active involvement and participation of students in the learning process. This can overcome geographical barriers and expand access to quality education for distance learning students, thereby creating a more inclusive and adaptive learning environment for individual needs.

Understanding molecular geometry is one of the challenging aspects in chemistry learning, especially for students who study independently through distance learning. There are students who have difficulty in visualizing three-dimensional molecules and interactions between atoms. To overcome this problem, an innovative and effective learning approach is needed. To understand molecular geometry, students need a strong understanding of basic ideas, such as Lewis structures, valence electrons, and electron configurations. This means that clear spatial visualization and additional learning materials are essential for molecular geometry education. For the purpose of visualizing abstract ideas, educational tools such as simulations and animations are invaluable. Learning in this cyber era is getting easier with the development of

many technologies. Teachers need to demonstrate something visually and then test their students' understanding of how the concept is presented disajikan (Schönborn & Anderson, 2010).

Distance Learning (DLE) allows students to access education without being limited by distance and time. In the context of chemistry learning, especially complex and abstract molecular geometry material, learning media are needed that can bridge physical and visual limitations. The Augmented Reality (AR) application developed in this study is designed to meet these needs. DLE students often face challenges in understanding abstract concepts without direct interaction with physical objects or demonstrations in class. With AR, students can visualize the shape and structure of molecules in three dimensions as if they were interacting directly with real objects.

The involvement of distance learning students in using AR applications such as BRIMOLANG not only facilitates the understanding of abstract concepts, but also allows them to learn independently in a more interactive and interesting way. The use of AR technology in this application allows the integration of chemical concepts with local culture, which can increase the relevance and referentiality of student learning. Thus, the existence of distance learning students, complex learning materials, and AR applications are closely related to creating a more effective and meaningful learning experience.

Previous research was conducted on students in face-to-face learning, while this study was conducted on distance education. In the learning process, distance learning is distinguished by the separation of students and lecturers. Various learning materials are available to students and they can apply them according to their respective learning styles and strategies. According to Moore dan Kearsley (2011), distance learning practitioners must be aware of three categories of interaction: interaction between students and instructors, interaction between students and teaching materials, and interaction between students. It is often seen that institutions that offer distance education only concentrate on developing one type of interaction, resulting in the underdevelopment of other categories of interaction. This must be avoided because distance learning students have diverse learning approaches.

The free time and opportunities available to certain distance learning students often lead them to study independently. They tend to be directly involved with the subject matter. They have limited opportunities to interact with their peers or lecturers/tutors. To facilitate optimal interaction with the material, distance learning must prepare high-quality teaching materials or

learning media for students that facilitate involvement and understanding of the subject matter. In order for UT to create quality distance learning, the implementation of UT must be based on seven principles: (1) Creating quality teaching materials; (2) establishing effective and efficient interactive contracts between UT and students in the learning process; (3) fostering collaborative learning between students by forming additional study groups; (4) building a feedback system with students; (5) requiring students to study intensively according to the time needed to study a teaching material; (6) communicating the high expectations of the community of workers to students, ensuring that UT graduates have high competence and do not disappoint the community; and (7) facilitating the uniqueness of students' interests, talents, and learning styles by providing various educational programs with appropriate learning media (Suparman, 2004).

The indicators used in this study are based on established evaluation methodologies and related literature studies (Anam et al., 2023). According to Riduwan (2012), the criteria for assessing the effectiveness of learning media utilize a Likert scale with four levels of answers: Strongly Agree, Agree, Disagree, and Strongly Disagree. This scale is used to measure various aspects of media quality, including content appropriateness, material accuracy, ease of use, and visual appearance. This approach allows researchers to quantify the results of the questionnaire and provide clear score weights for each aspect assessed.

This study aims to assess the effectiveness of AR application with ethnochemical approach in improving the understanding and learning achievement of distance learning students in molecular geometry material. Specifically, this study will evaluate whether the use of AR can help students better understand molecular structures and related concepts compared to conventional learning methods. The findings of this study are expected to provide significant benefits for distance learning students in helping them understand the concept of molecular geometry better using AR technology. In addition, this study is anticipated to contribute to chemistry teaching methods, especially in the context of distance learning and culture-based approaches. By combining modern technology with regional knowledge, this approach can be a model for the development of learning in other fields.

2 METHODOLOGY

Research with the aim of describing the success of a product accurately, relevantly, quickly, and effectively can be described as an evaluative and descriptive design (Dharma, 2008). Using an ethnochemical approach in Palembang, this study includes a continuation of a series of augmented reality-based learning media testing procedures that include molecular geometry material (Wijayanti, 2023). In this investigation, questionnaires were distributed to respondents identified through non-random sampling. Students of the Chemistry Education Study Program, Universitas Terbuka became the respondents selected for the study. The selection of respondents was based on their scholastic or professional background in education or chemical technology, which enabled them to evaluate or provide learning media products.

This investigation uses a questionnaire as its data collection methodology. The next step in creating mobile learning media is to process and analyze the data collected from the questionnaire. By using the specified indicator score weights, this study uses a quantitative descriptive analysis approach to assess questionnaire responses. This study highlights the features of all collected data sets. Based on the findings of the data analysis, the application was revised to refine the development process. The methodology used in this investigation is:

1. Compiling and collecting questionnaire data;
2. Processing and calculating data to determine the percentage in each category;
3. By comparing the response scale value with the maximum answer scale value then multiplying it by 100%, the formula for calculating the percentage method on the Likert scale can be obtained.

$$\text{Eligibility Percentage (\%)} = \frac{Total\ Assessment\ Score}{Total\ Maximum\ Score} \times 100\%$$

The level of feasibility of the developed application is determined by categorizing the calculation results in the form of a percentage according to the criteria using a rating scale. The calculation of the Likert scale score shows that the developed product is feasible to use if the interpretation is ≥ 60% (Riduwan, 2012). Table 1 summarizes the descriptive quality criteria assessed.

Table 1. Descriptive Quality Criteria with Rating Scale

Assessment level	Description
Number 0-20%	Not Very Good
Number 21-40%	Less Good
Number 41-60%	Fair
Number 61-80%	Good
Number 81-100%	Very Good

One of the data analysis methods used in this study is quantitative descriptive analysis, which involves weighting the questionnaire scores based on predetermined variables. Each data set collected was characterized using this methodology.

3 FINDINGS AND DISCUSSION

This study examines the application of Augmented Reality (AR) with an ethnochemical approach for learning molecular geometry in the context of Distance Education (distance learning). The integration of ethnochemical elements adds educational value, allowing students to feel the relevance of the material to their real lives, which effectively increases motivation and relevance of learning. By using an ethnochemical approach in Palembang, this study includes a continuation of a series of procedures for testing augmented reality-based learning media that include molecular geometry material (Wijayanti, 2023).

The integration of AR in molecular geometry learning shows great potential in visualizing abstract concepts in three dimensions, which are often difficult to understand through conventional learning. In addition, this application also supports students' independent learning in distance learning, enriching the learning process with a more interactive and in-depth experience. Ethnochemistry as an approach that links chemical concepts with local culture can strengthen students' understanding by connecting theory with real practice.

The main difficulty faced by students is the visualization of molecular structures and interactions between atoms. AR provides a solution by projecting microscopic objects into a larger and interactive scale. Evaluation of the use of this application among students showed a significant increase in conceptual understanding and the ability to apply knowledge in real contexts. The results show that the integration of local wisdom through ethnochemistry not only improves theoretical understanding but also strengthens student engagement in the learning process. This is especially important in areas with limited access to conventional learning

resources because it can create a more inclusive and adaptive learning environment to individual needs.

This research produces a mobile learning application called "BRIMOLANG: Learning Molecular Shapes through Palembang Culture", which is compatible with the Android operating system and can be accessed via smartphone. The contents of this media include AR simulations, materials, learning videos, assessments, ethnochemical articles, and application specification information that is in accordance with the findings of the student needs analysis. The following are the results of the implementation analysis in the form of a feasibility test of the development of AR-based mobile learning on the molecular geometry material that has been developed.

3.1 Mobile Learning Feasibility Test

The empirical media feasibility test or media trial is intended to test the feasibility of the media and see the opinions of users of the mobile learning media that has been developed. The media trial was conducted on 310 respondents who were distance learning students from the Chemistry Education Study Program, Universitas Terbuka who used smartphones based on the Android operating system. The first step, the researcher provided a Google Drive link containing the application "BRIMOLANG: Learning Molecular Shapes through Palembang Culture" to respondents via WhatsApp Group with a data collection duration from May to June 2024. After the application was installed, respondents could explore the downloaded application. Furthermore, respondents were given a written media trial questionnaire to provide an assessment of the mobile learning that had been developed. The questionnaire consisted of 36 questions categorized into eight categories that were evaluated by respondents during the media trial. These categories include presentation feasibility, content suitability, language suitability, utilization of AR technology, usefulness, visual and audio appearance of mobile learning utilization of ethnochemical content, and implementation and software engineering. Table 2 shows the results of the media trial determined through calculations.

Table 2. Results of Small-Scale Media Trials by Distance Learning Students

No.	Aspect	Items	Average Percentage (%)	Criteria
1	Feasibility of Mobile Learning Presentation	1—4	78,7	Good
2	Feasibility of Mobile Learning Content	5—10	84,1	Very Good
3	Appropriateness of Mobile Learning Language	12—15	85,8	Good
4	Use of AR in Mobile Learning	11, 16, & 17	89,7	Very Good
5	Benefits	18—21	88,3	Very Good
6	Visual and Audio Display of Mobile Learning	22—30	83,5	Very Good
7	Use of Ethnochemistry	31—33	86,2	Very Good
8	Implementation and Software Engineering	34—36	79,6	Good
Overall Score Average			84.5	Very Good

The presentation of the results of the BRIMOLANG mobile learning media trial is as follows.

3.1.1 Feasibility of Mobile Learning Presentation

The aspect of "feasibility of presentation" in mobile learning media consists of four questions which are divided into two indicators, namely the truth of the material content and the suitability of the material to basic competencies. From the average percentage of feasibility of each indicator, it is set at 78.7%. This means that the "Good" criteria are met during the BRIMOLANG mobile learning presentation feasibility testing procedure.

3.1.2 Suitability of Mobile Learning Content

The aspect of "suitability of content" of this mobile learning media consists of six questions and two indicators, namely the technique of presenting material and supporting material presentation. By calculating the average percentage of suitability of each indicator, it is set at 84.1%. The content on BRIMOLANG mobile learning has met the criteria of "Very Good" as evidenced by the percentage displayed.

3.1.3 Mobile Learning Language Suitability

The aspect of "language suitability" in this mobile learning media consists of four questions with four indicators, namely sentence effectiveness, communicative, dialogic and interactive, and suitability with language rules. Based on the average percentage of suitability for each indicator, it was obtained at 85.8%. This percentage shows that the language suitability has met the criteria of "Very Good" for BRIMOLANG mobile learning.

3.1.4 Use of AR in Mobile Learning

The aspect of using AR in BRIMOLANG mobile learning consists of three questions with one indicator, namely the AR component. Based on the average percentage of the feasibility of each indicator, it was obtained at 89.7%. This means that the use of AR has met the criteria of "Very Good" in mobile learning.

3.1.5 Usefulness

This aspect of "usefulness" consists of four questions and two indicators: user interest in the material after mobile learning and the media's capacity to facilitate the acquisition of molecular geometry knowledge. The figure was set at 88.3% by calculating the average percentage of suitability for each indicator. Based on this percentage, the mobile learning media has met the criteria of "Very Good" in terms of its usefulness.

3.1.6 Visual and Audio Display of Mobile Learning

Ten questions with five indicators including layout accuracy, design suitability, image clarity, writing suitability, and video quality become the "visual and audio display" of BRIMOLANG mobile learning. The figure is calculated at 83.5% with an average percentage of eligibility for each indicator. The visual and auditory presentation of BRIMOLANG mobile learning is considered "Very Good" based on this percentage

3.1.7 Use of Ethnochemical Content

The aspect of "use of ethnochemical software" consists of three questions and one indicator, namely the integration of ethnochemical context into the material. By calculating the average percentage of eligibility for each indicator, it is set at 86.2%. This means that the use of content is considered "Very Good" and has met these criteria.

3.1.8 Software Engineering and Implementation

The aspect of “implementation and software engineering” consists of three questions and one indicator, namely ease of use of the media. The average percentage of eligibility for each indicator is 79.6%. Thus, the implementation and software engineering are considered “Good” and meet the applicable criteria.

Mobile learning media obtained an aggregate average of 84.5% with an interpretation of "Very Good" based on the percentage results of the seven aspects. The aspect of AR utilization in mobile learning media has the highest average value of 89.7%. This proves that the use of AR in molecular geometry material has a positive response because it can increase motivation in the learning process. In line with the findings of Sungkur, Panchoo, dan Bhoyroo (2016), it was revealed that AR applications have been proven to facilitate understanding of complex concepts that are very challenging for the average distance learning students. AR has revolutionized the learning experience by allowing students to understand complex concepts easily and visualize events that are happening. Nurhasanah's additional research also shows that AR can improve students' understanding of science concepts (Nurhasanah dkk., 2019)

The development of BRIMOLANG research is based on the research of Cai et al. (2014) who found virtual and augmented reality-based learning tools to be the most praised microstructure learning media in recent years. Singhal et al. (2012) revealed an efficient method in designing and interacting with molecules to understand the spatial relationships between them provided by Augmented Chemistry.

Augmented Reality (AR) has become the subject of extensive development research in the field of learning media. For example, ARchemy allows students to represent complex 3D concepts visually (Abdinejad et al., 2021). This BRIMOLANG study uses an ethnochemical approach context in its learning process as a novelty or strategy in improving user understanding in studying molecular geometry material remotely. Several features including journals, diagrams, practice-oriented instructions, and multiple-choice questions are integrated into the development of mobile augmented reality for acid-base titration material by Alfaro et al. (2022). On the other hand, this application must change certain features and provide more explicit instructions for subtasks. Next, ARchemist is a laboratory assignment administration system that assists students in organizing procedures and steps for practicums (Yang, 2018). However, to prevent work accidents, the implementation of the practice requires direct supervision by

teachers or laboratory assistants. This AR-facilitated learning media is very suitable for the needs of 21st century education. Therefore, the progress of this media may continue.

In addition to the assessments, respondents provided the following comments and recommendations.

"I feel that my learning experience with this application is quite good and the material is easier to understand. It would be very helpful if background music was added to the application to make it more interesting. In my opinion, music can create a more enjoyable learning atmosphere and support concentration and understanding of the material so that it is not only informative but also more entertaining and interactive." (Respondent 5's Suggestions and Comments, 2024)

"I think that this mobile learning application is good and works well. However, it would be even more useful if this application could also be accessed by IOS users and available for download via the Appstore. This will expand the reach of users and facilitate access for those who use Apple devices so that all users can take advantage of the features of this application without compatibility constraints." (Respondent 1's Suggestions and Comments, 2024)

Respondents gave praise and some suggestions related to mobile learning that can be accessed using IOS, music background, bugs, and display colors. The media will be improved according to the suggestions and comments given because mobile learning was developed by the researcher himself so that it does not have official permission to be installed on IOS and uploaded to the Appstore.

The use of BRIMOLANG has been proven to provide significant benefits in improving students' understanding of abstract concepts in chemistry, especially in molecular geometry material. AR technology allows for real and interactive visualization of microscopic objects, which is difficult to achieve through conventional learning methods. With AR, students can observe and interact with three-dimensional molecular models, strengthening their understanding of molecular structure and dynamics. This is in line with previous findings that show that the use of AR in learning can improve students' mental models and facilitate understanding of complex concepts (Latipah, 2021; Sungkur, 2016)

The ethnochemistry approach that integrates local cultural values into the learning process also provides additional benefits. In the context of BRIMOLANG, this approach not only makes the subject matter more relevant to students' daily lives but also increases their motivation to learn. Students can see firsthand the application of chemistry concepts in their cultural context which

helps connect theory to real practice. Previous research has shown that ethnochemistry can strengthen students' understanding and engagement in learning by linking scientific concepts to local culture (Selasih & Sudarsana, 2018). Thus, the combination of AR and ethnochemistry in the BRIMOLANG application has succeeded in creating a more meaningful and contextual learning experience for distance learning students.

Overall, the integration of AR and ethnochemistry in chemistry learning media not only enhances theoretical understanding but also encourages active involvement of students in the learning process. This is especially important in the context of Distance Education which often faces challenges in providing interactive and immersive learning experiences. Through AR technology, students can learn independently in a more interesting and efficient way, while the ethnochemistry approach ensures that learning remains relevant and meaningful. Thus, the BRIMOLANG application not only meets the needs of 21st century learning but also expands access to quality education for distance learning students, creating a more inclusive and adaptive learning environment to individual needs.

4 CONCLUSION

Students who take distance learning can more effectively understand the complexity of molecular geometry material by utilizing AR-based devices and mobile learning components. This mobile learning application was developed to be feasible and visually appealing, increasing the possibility of being implemented as a learning resource in the classroom. This is because the product has been validated by material and media experts, as well as by students who evaluate it. This research includes product development and validation procedures. The product produced by this study is a learning resource in the form of a mobile learning application that is expected to be able to improve understanding of molecular geometry material. The use of AR in molecular geometry material has a positive response because it can increase motivation in the learning process. By utilizing AR technology, users can visualize the molecular geometry to be observed. BRIMOLANG mobile learning is suitable for use as a learning medium for molecular geometry material. This media has the potential to facilitate learning by utilizing AR technology which not only improves students' understanding of the material but also sharpens their spatial abilities. The "BRIMOLANG" mobile learning media can be used as a learning aid for learning molecular geometry material anytime and anywhere.

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